THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

VISUAL REFERENCE STANDARDS FOR WELD SURFACE CONDITIONS (PHASE II)

U.S. DEPARTMENT OF TRANSPORTATION
MARITIME ADMINISTRATION

IN COOPERATION WITH
NEWPORT NEWS SHIPBUILDING

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CONTENTS

FOREWORD

The purpose of this report is to present the results of Phase II of a research and development program which was initiated by the members of the Ship Production Committee of The Society of Naval Architects and Marine Engineers and cost shared by U.S. Maritime Administration, the American Bureau of Shipping and Newport News Shipbuilding. The effort of this project was directed to the development of three dimensional sample illustrations of weld surface conditions, "applicable to visual weld inspection.

Phase I addressed the conditions of cluster porosity, scattered porosity, and undercut; Phase II addresses the conditions of weld surface roughness, irregular contour, and re-entrant angle.

Special acknowledgment is made to the members of Welding Panel SP-7 of the SNAME Ship Production Committee who served as technical advisors in the preparation of inquiries and evaluation of subcontract proposals; to Mr. B.C. Howser, Newport News Shipbuilding, SP-7 Panel Chairman and to Mr. M.I. Tanner, Newport News Shipbuilding, SP-7 Program Manager.

The program was carried out by the American Bureau of Shipping under the direction of Mr. I.L. Stern Mr. M.F. Wheatcroft was the Project Manager; Dr. D.Y. Ku, Mr. R.F. Waite and Mr. D. Cantore served as Project Engineers.

Appreciation is expressed for the contribution of weld samples by the following companies:

- Avondale Shipyards, Inc.
- Bath Iron Works Corporation
- Bay Shipbuilding Corporation
- Bethlehem Steel Corporation
- FMC Corporation
- Fraser's Boiler Service
- General Dynamics Corporation
- Ingalls Shipbuilding Division
- Newport News Shipbuilding
- Tacoma Boatbuilding Company
- Todd Pacific Shipyards Corporation

Plastic model replicas of the reference weldments were prepared by Newport News Shipbuilding to facilitate presentation to the Panel

VISUAL REFERENCE STANDARDS

FOR

WELD SURFACE CONDITIONS

(PHASE II)

AUGUST 1985

AMERICAN BUREAU OF SHIPPING

65 BROADWAY

NEW YORK, N.Y. 10006

ABSTRACT

Samples were produced illustrating three types of weld surface condition. Roughness and irregular contour samples were produced at three severity levels in butt and fillet welds; re-entrant angle samples of butt and fillet welds were produced illustrating various angles around 90 degrees. The samples could form the basis for a guide for the description and evaluation of weld surface conditions which could be applicable to various structural and pressure vessel applications. The use of such illustrations, replicated as plastic models, could reduce the frequency of making physical measurements of weld surface conditions, and also reduce subjective considerations in evaluating weld surface conditions.

INTRODUCTION

Visual inspection is the most extensive nondestructive method used for weld evaluation. Judgments as to the acceptability of welds based on visual examination may be controversial in that existing codes and specifications lack sufficiently clear and objective criteria for certain weld surface conditions. Some codes define the acceptable level of some surface conditions quantitatively (e.g. size and number of pores, depth of undercut, etc...); others use general descriptive terms (e.g. "reasonably free from undercut and overlap"). Irregularities in weld surface conditions along the length of the weld or transverse to the weld are difficult to define quantitatively; however, it is generally agreed that at some level, such irregularities should be considered indicative of a weld of unacceptable quality on the basis of a subjective judgement. When subjective judgement is involved, experts may not always agree on the acceptance of a given weld, even when evaluated against a descriptive standard. Consequently, there is an apparent need to reduce the subjective considerations involved and to augment descriptions in existing codes and specifications.

In the course of the deliberations of the SNAME SP-7 Welding Panel, it was agreed that a viable approach to meet this need would be the development of plastic replicas of welds with various gradations of different weld surface conditions and with supplementary descriptions.

This report represents the second phase of an overall program to develop three-dimensional sample illustrations of weld surface conditions which could be used as reference standards by shipyards, specification writing bodies, technical societies and fabricators. Phase I of this project developed samples representing scattered porosity, cluster porosity, and undercut. In Phase II samples illustrating roughness, irregular contour, and re-entrant angle were developed.

OBJECTIVES

The objectives of Phase II of the program were as follows

a) To develop samples illustrating weld surface roughness and weld contour (including re-entrant angle, oveflap, convexity and concavity) with appropriate gradations of severity.

b) To relate the illustrated conditions to existing descriptive standards used in the maritime industry.

c) To provide a basis for communicating conditions not amenable to quantitative written descriptions.

d) To present a basis for utilization of the samples for marine applications by shipyards, specification writing bodies, technical societies and fabricators.

A future objective, outside the scope of this phase, was to replicate the selected weld surface conditions as plastic models and provide a basis for their distribution to fulfill objective "d" above.

APPROACH

The approach was to augment the descriptive visual acceptance standards presently used in the marine industry. The following standards were addressed (pertinent sections are summarized in Tables I, II and III):

1a. U.S. Department of the Navy MIL-STD-1689 (SH) Fabrication, Welding, and Inspection of Ships Structure.

lb. U.S. Department of the Navy NAVSEA 0900 -LP-O03-8000 Surface Inspection Standard For Metals.

2. American Welding Society (AWS) D.1.l Structural Welding Code - Steel (Workmanship)

3. American Bureau of Shipping (ABS) Rules For Building and Classing Steel Vessels.

4. American Society of Mechanical Engineers (AS ME) Section I - Power Boilers

5. ASME Section VIII Division 1- Pressure Vessels.

6. American Petroleum Institute (API) RP2A Recommended Practice For Planning, Designing, and Constructing Fixed Offshore Platforms.

7. API 650 Welded Steel Tanks For Oil Storage.

The initial approach was to produce samples illustrating the following surface conditions in butt and fillet welds:

Roughness
Contour (including re-entrant angle, overlap, convexity and concavity)

Upon further consideration, it was determined that overlap, convexity and concavity should be eliminated from the program since they were adequately defined in codes and/or could be conveniently measured with standard gauges.

The three conditions which were addressed are: roughness, irregular contour and re-entrant angle. They are defined as follows:

a) Roughness: Condition of surface irregularities along the longitudinal axis of the weld.

b) Irregular contour: Condition of surface irregularities along the transverse axis of the weld.

c) Re-entrant angle: The angle between the plane of the parent metal surface and a plane tangential to the weld bead surface at the toe (See Fig. A).

PROCEDURE

The SNAME SP-7 Welding Panel members were requested to submit samples, which in their individual judgment could represent criteria for the following:

1) The minimum quality appropriate to critical applications.

2) The minimum quality level appropriate to general applications.

3) The minimum quality level appropriate to secondary applications.

A total of 120 samples representing various gradations of roughness, irregular contour and re-entrant angle were provided by eleven (11) members of the SNAME SP-7 Welding Panel. The selection of representative samples illustrating roughness and irregular contour was based on the consensus of the members of SNAME SP-7 Welding Panel The selection of representative samples illustrating re-entrant angle was selected based on actual measurements revolving around 90 degrees. Methods using protractors, wire transfer gauges and templates yielded erratic and inaccurate measurements. The procedure which proved satisfactory was conducted as follows:

1. Weld samples were replicated with pliable epoxy to produce negative impressions.

2. The epoxy impressions were then used to produce positive plaster impressions of the weld samples.

3. These positives were then sectioned at several locations in order to permit accurate measurement of their re-entrant angle by means of an optical comparator.

The final selection process for the reference standards was as follows:

Sorting and measuring
Review, selection and discussion with the Ad-Hoc SP-7 Committee
Preparation of additional samples as required
Review and final selection by the SP-7 Welding Panel

Each reference standard was machined to the following dimensions:

Butt weld - 6“ L x 2“ W x 0.5” T
Fillet weld - 6“ L x 1.5” W x 2“ H x 0.5” T

The six inch length was chosen because many codes address the allowable distribution of weld surface conditions in multiples of six inches of weld length.

The selected roughness and irregular contour samples, photographed at 1X magnification, are shown in Figures B through E. The selected re-entrant angle samples together with cross sections of the positive plaster models also photographed at 1X, are shown in Figures F through G.

DISCUSSION

The use of replicas of conditions to augment descriptive text has precedent in many areas of materials and welding, such as: gas cut edge conditions and surface roughness comparisons. The value of such replicas is in minimizing differences of opinion in interpreting written text relating to a condition difficult to describe quantitatively. Another potential benefit is that the use of illustrative samples or models permits inspection to be made rapidly, with a minimum need for gauge measurements, thereby reducing inspection costs.

Depicting relative levels of roughness and irregular contour is made difficult by the imprecise language to describe the condition in existing codes: For example:"..... provided (welds) are sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges or valleys " and "...., the contour of welds, ... shall blend smoothly and gradually into the base metal" (See Tables I and II). -An SP-7 Panel consensus as to quantitative criteria to more precisely delineate the conditions of irregular contour or roughness could not be reached; thus the preparation of the samples in terms of condition severity appropriate to each level of application was left to the judgement of each shipyard and the general description given in the Approach.

CONCLUSIONS

1. Samples illustrating weld surface conditions have been developed which can be used to augment written welding codes.

2. Two sets of samples of butt and fillet welds have been produced; each set illustrates three levels of severity of surface condition for roughness and irregular contour and one butt and fillet weld illustrate re-entrant angles near 90 degrees.

RECOMMENDATIONS

It is recommended that the proposed basis for visual illustrations of weld surface conditions, i.e., descriptions of weld surface conditions accompanied by three-dimensional replicas of these conditions be presented to pertinent code writing bodies for their consideration for use in connection with published codes.

FUTURE WORK

1. A proposal for replication of the selected and adopted illustrations of weld surface conditions as plastic models in sufficient quantities for promulgation to the Marine Industry will be submitted to the SNAME SP-7 Welding Panel Upon approval of the above proposal it is expected that the reference replicas, including those adopted in Phase I in combination with appropriate text, will be submitted for consideration for Ship Classification Society use as a guide for the evaluation of weld surface conditions.

TABLE I

SUMMARY OF ACCEPTANCE STANDARDS

(IRREGULAR CONTOUR)

MIL-STD-1689 (SH) Fabrication, Welding and Inspection	not addressed
NAVSEA 0900-LP-O03-8000 Surface Inspection	not addressed
AWS D1.1 Structural Welding Code	not addressed
ABS Section 30.5.8. a Steel Rules	The surfaces of welds . . . . are to be regular and uniform.
ASME Section I Power Boilers	not addressed
Section VIII Div.1 Pressure Vessels	not addressed
API RP 2A Fixed Offshore Platforms	not addressed
API 650 Welded Steel Tanks	not addressed

TABLE II
SUMMARY OF ACCEPTANCE STANDARDS
(ROUGHNESS)

MIL-STD-1689 (SH) Fabrication, Welding and Inspection	not addressed
NAVSEA 0900-LP-O03-8000 Surface Inspection	not addressed
AWS D1.1 Structural Welding Code	not addressed
ABS Section 30.5.8.a Steel Rules	The surfaces of the welds.... are to be regular and uniform.
ASME Section I PW 35 Para. 35.1 Power Boilers	The surfaces of the weld may be left “as welded” provided they are sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys.
Section VIII Div. 1 UW35 Pressure Vessels	The surface of the weld may be left “as welded” provided the weld is free of coarse ripples, grooves, overlaps, abrupt ridges or valleys.
API RP2A Fixed Offshore Platforms	not addressed
API 650 Welded Steel Tanks	not addressed

TABLE III

SUMMARY OF ACCEPTANCE STANDARDS

(RE-ENTRANT ANGLE)

MIL-STD-1689 Para 8.3.1 Fabrication, Welding and Inspection	Except as required for NDT, the as-deposited surfaces at the weld edge shall be acceptable provided they do not form a re-entrant angle less than 90 degrees with the base plate.
NAVSEA 0900-LP-O03-8000 Para, 5.2.1.6 Surface Inspection	When required . . . . . the contour of welds, with the exception of undercut within specification allowances, shall blend smoothly and gradually into the base metal.
AWS D.1.l Para. 3.6.2 Structural Welding Code	In the case of butt . . . . . the reinforcement . . . . shall have gradual transition to the plane of the base metal surface.
ABS Section 30.5.8a Steel Rules	The surface of the welds are to be . . . reasonably free from . . . overlap.
ASME Section I Power Boilers	not addressed
Section VIII Div. 1 Pressure Vessels	not addressed
API RP 2A Para.6.4.l Fixed Offshore Platforms	Weld profiles . . . . should merge smoothly with the base metal of both brace and chord.
API 650 Para 5.2.Ld Welded Steel Tanks	The edges of all welds shall merge with the surface of the plate without a sharp angle.

GREATER OR EQUAL TO 90 DEGREES

LESS THAN 90 DEGREES

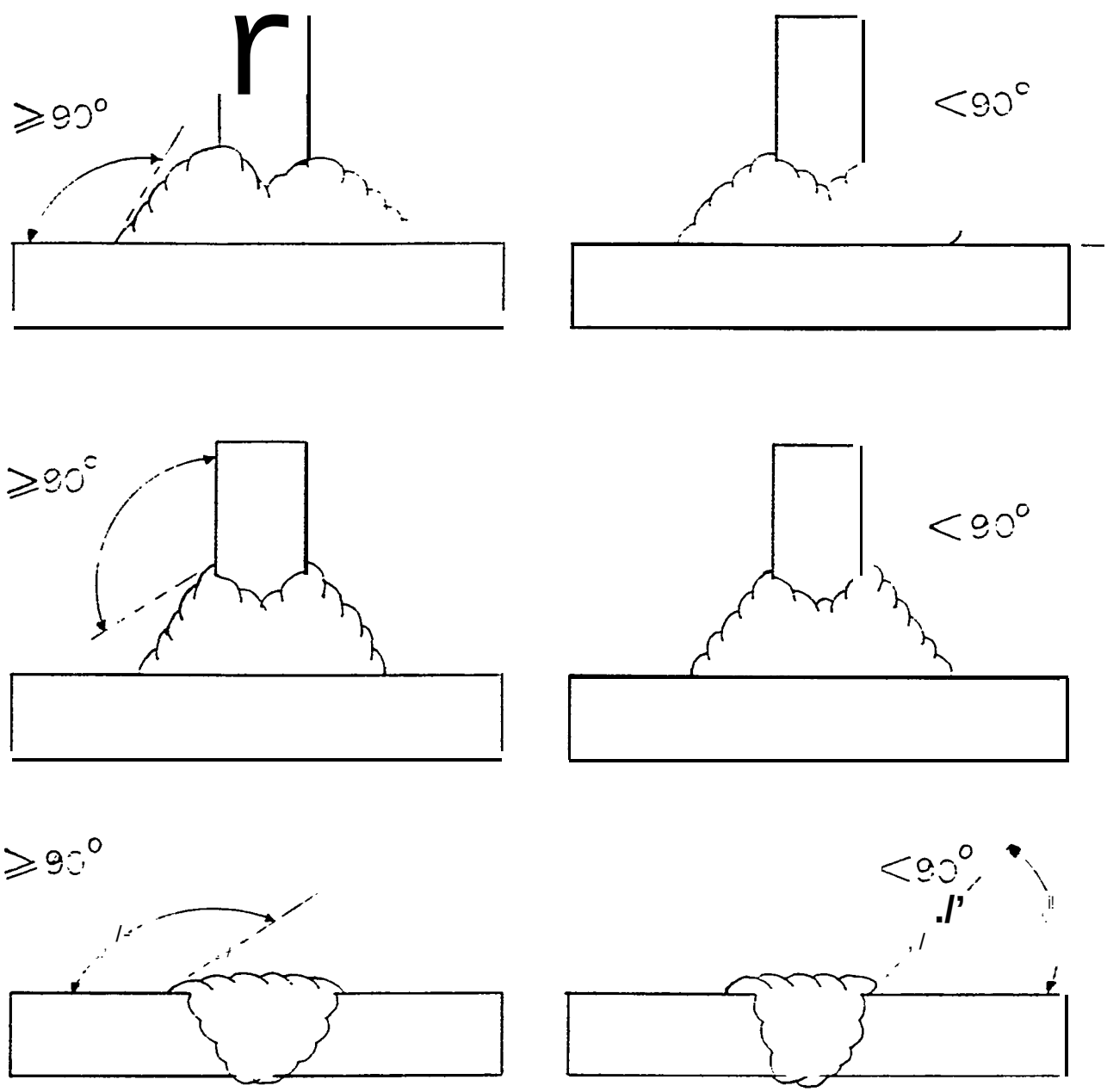
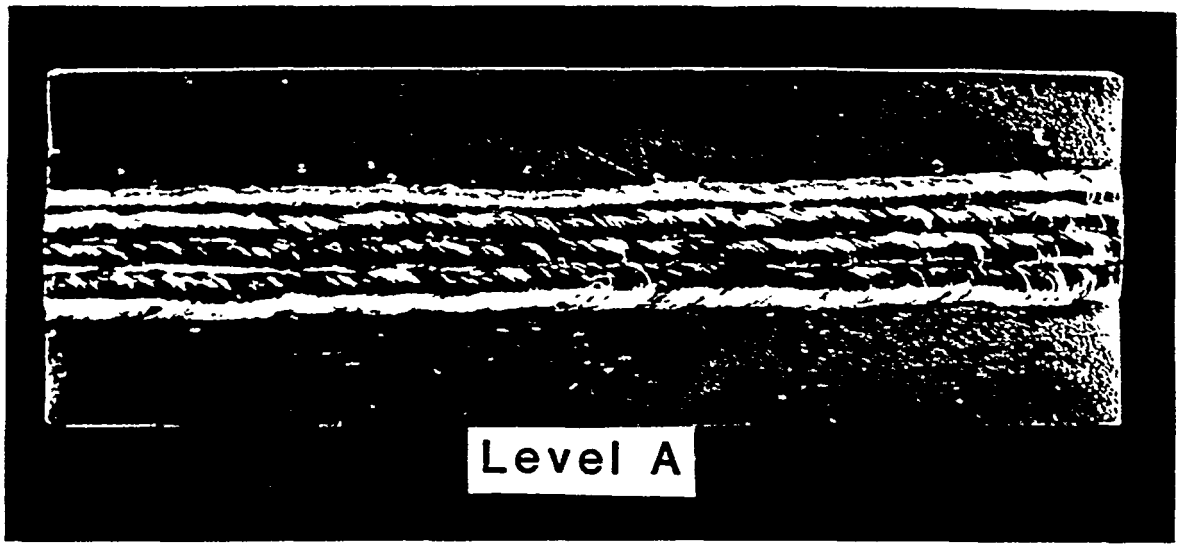
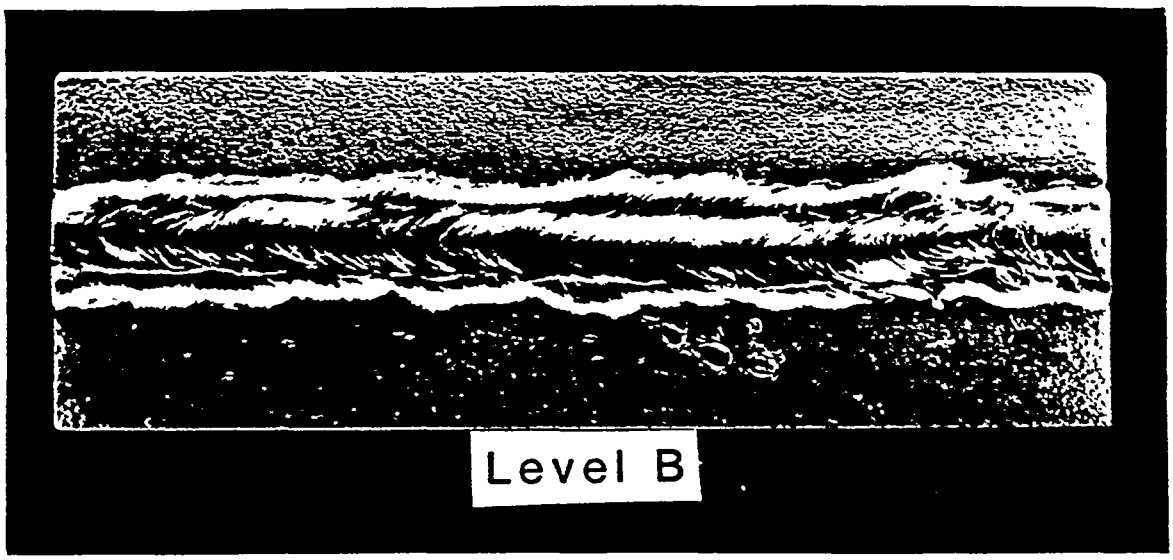


FIG . A RE-ENTRARiT ANGLES





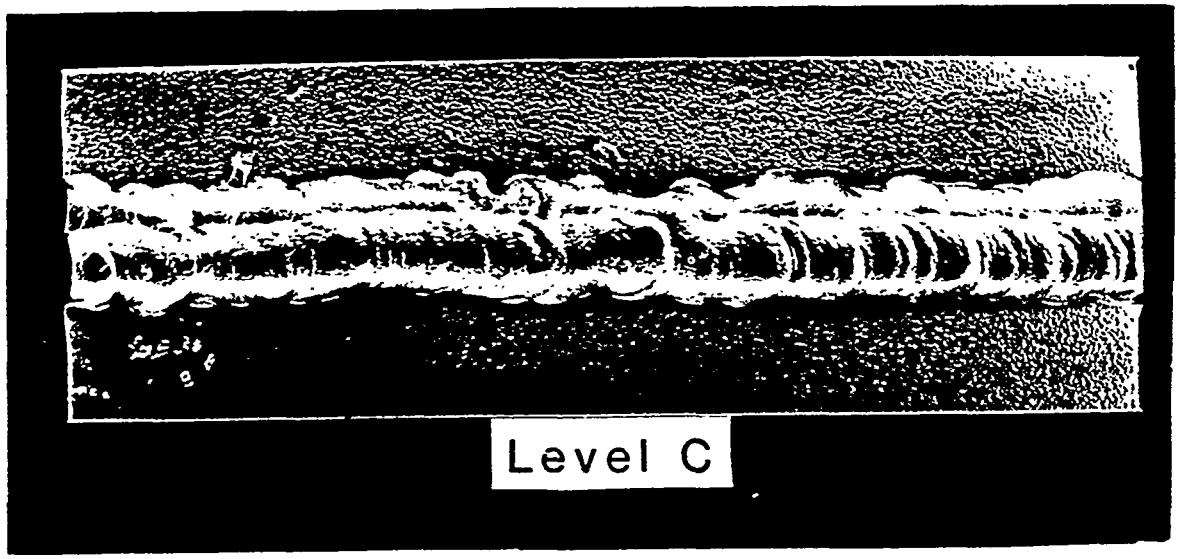


Fig. B: Contour

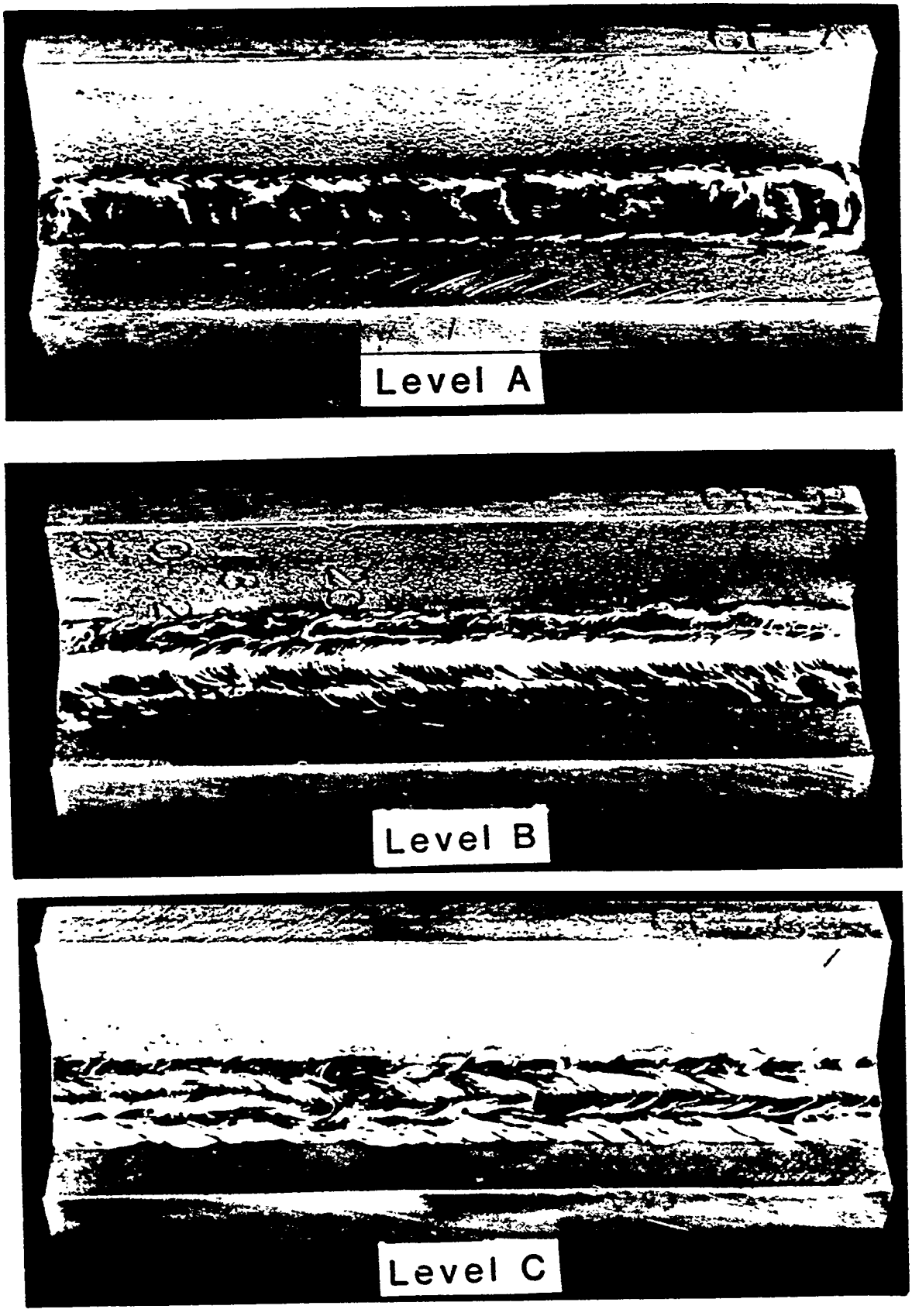
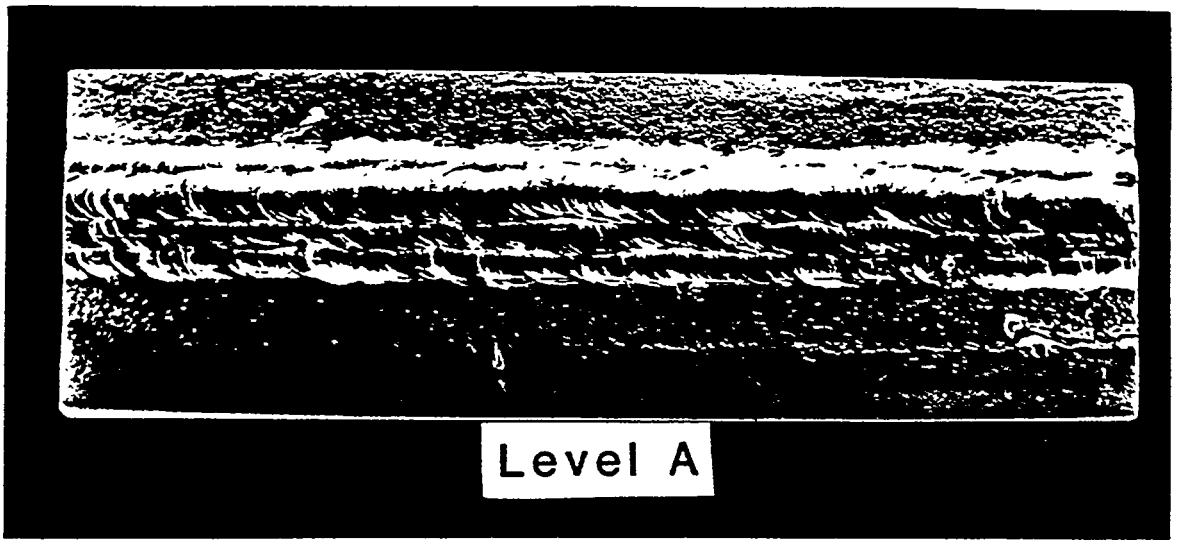
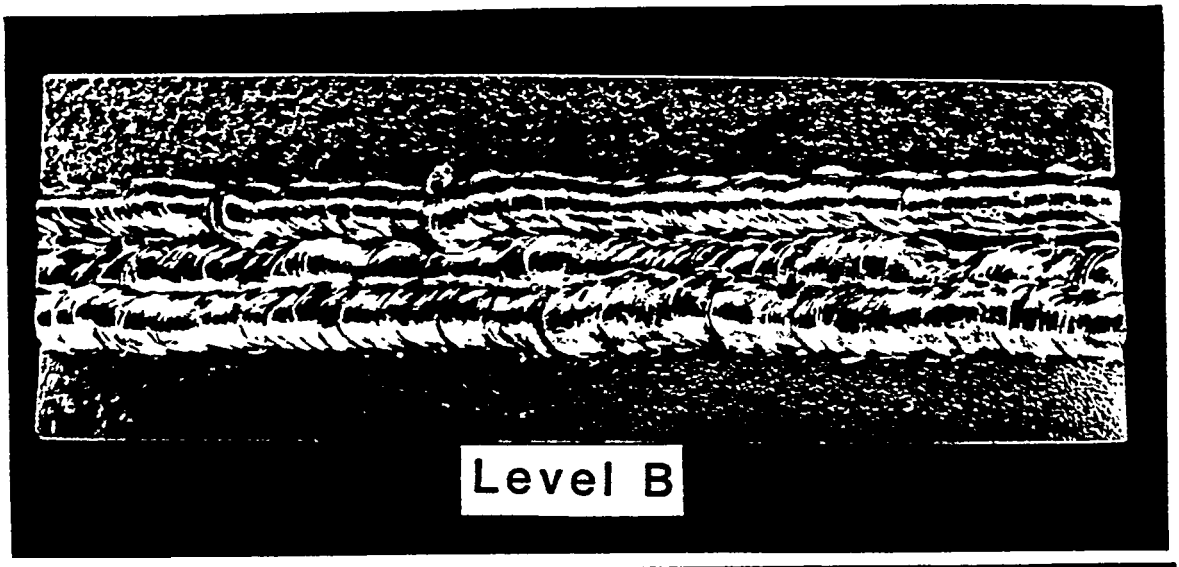


Fig. C: Contour





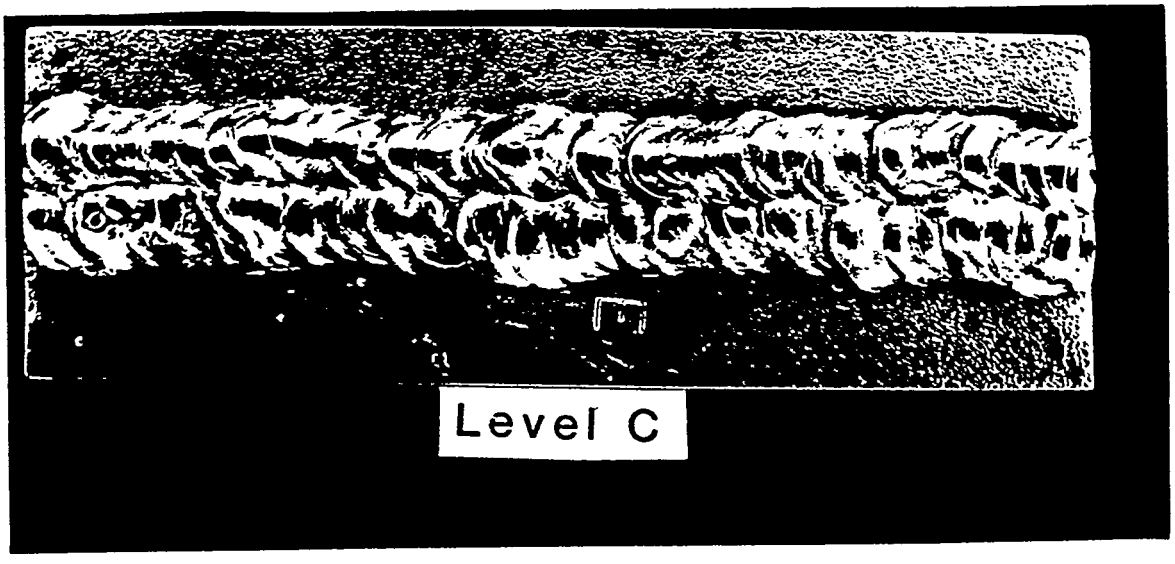
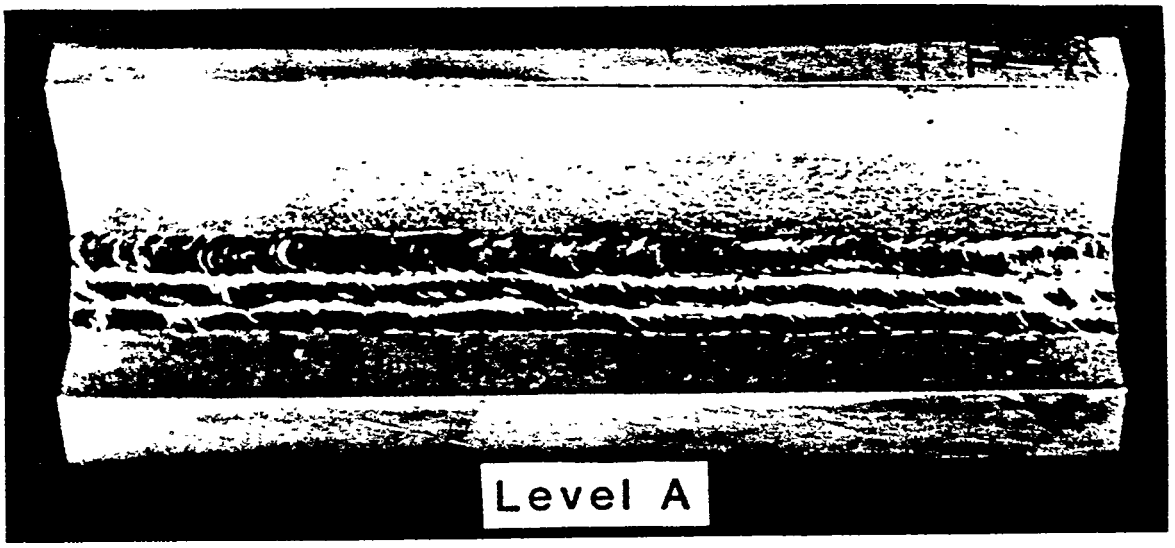
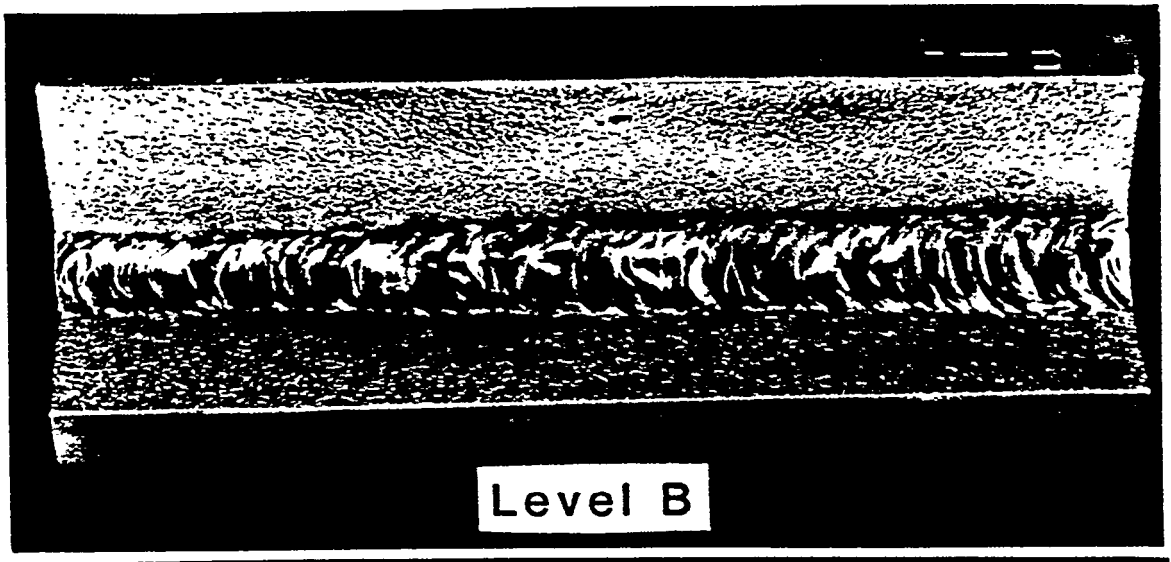


Fig. D: Roughness





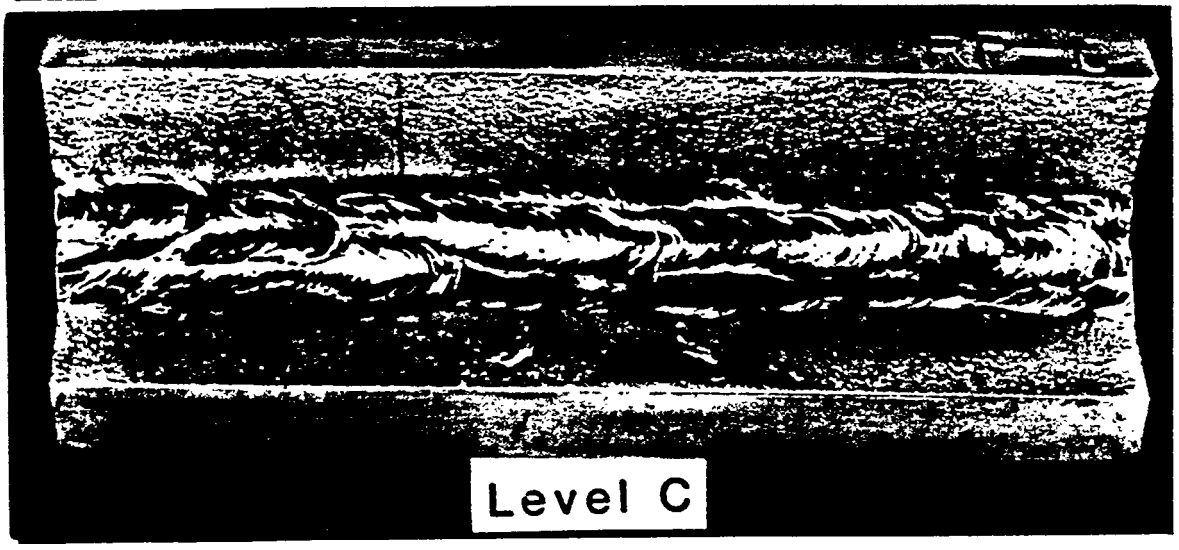
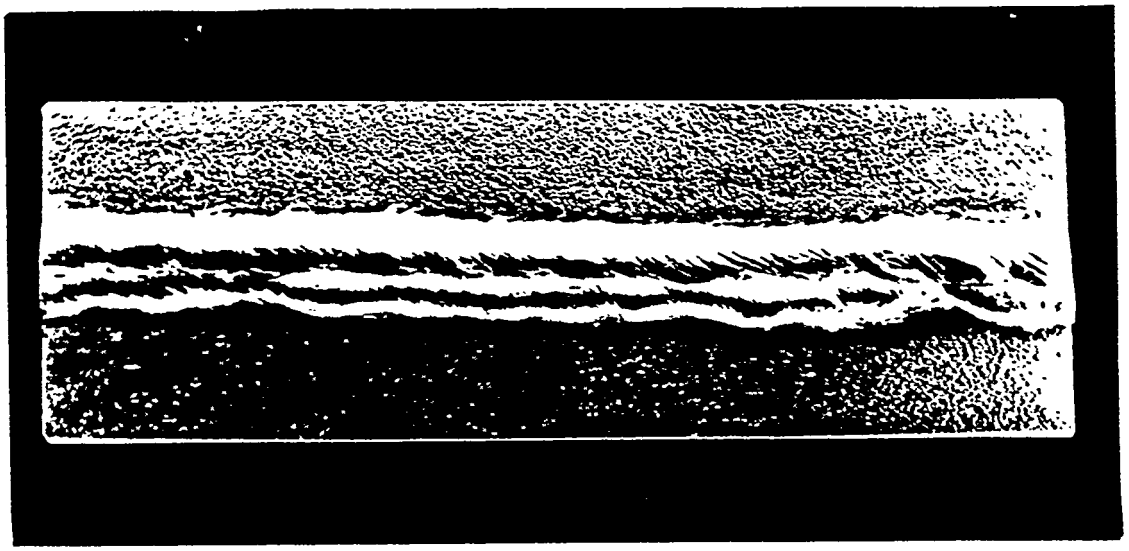
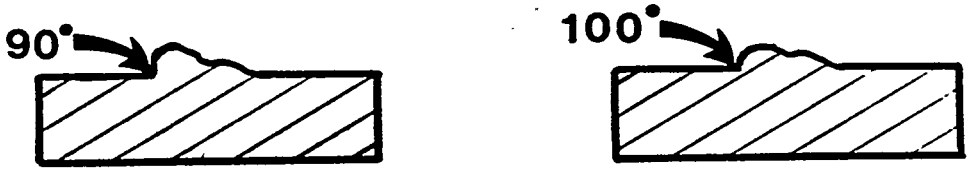


Fig. E: Roughness





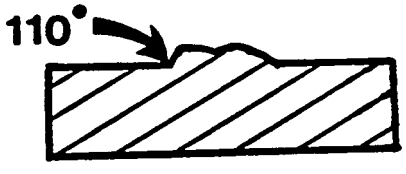
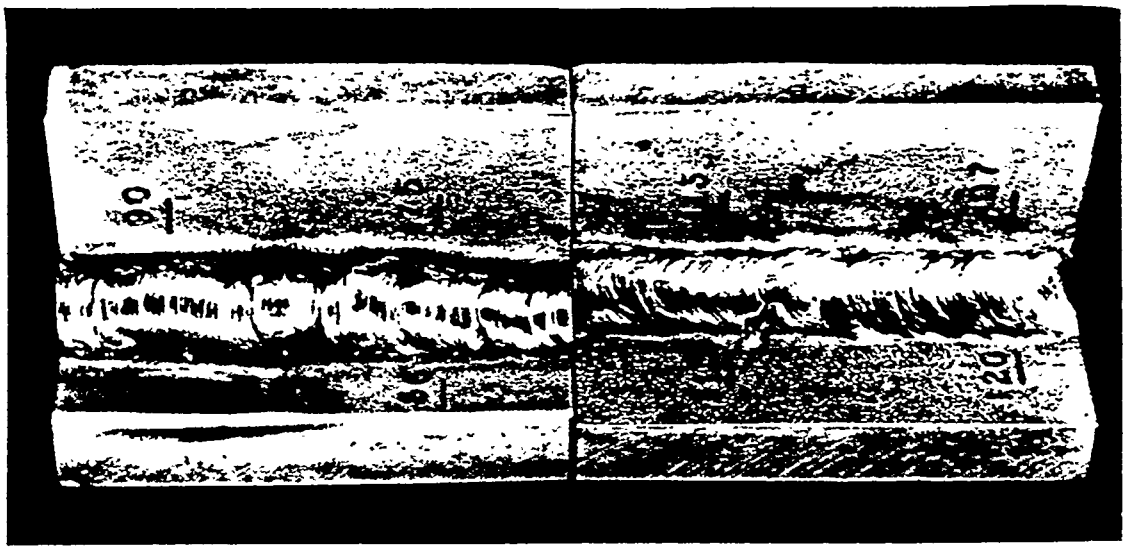
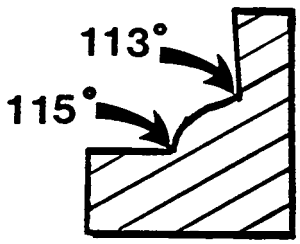
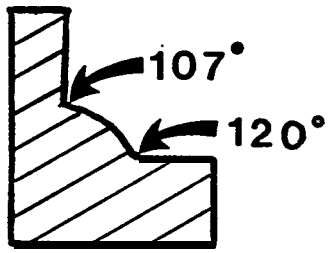
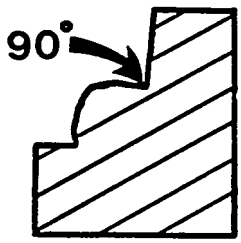


Fig. F: Re-entrant Angle









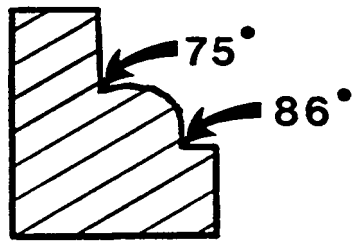


Fig. G: Re-entrant Angle